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Multi-Address Digital Command System

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AEROSPACE ENGINEERING DIVISION PROJECT 7659
GEOPHYSICS LABORATORY
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The Model 2A Multi-address Digital Command System can provide 95 commands for transmission to each of 10 addresses in a balloon-borne scientific payload. To prevent false-command activation, the balloon-borne decoder checks the station address, performs a double-scan parity check, and generates a reply code that is telemetered back to ground control for verification before the Execute command is issued. The system is operable with HF, VHF and UHF communications systems, both AM and FM. Since 1986 it has been flown routinely on Geophysics Laboratory scientific balloon payloads with error-free operation.

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Preface*

This work was a cooperative effort between the Air Force Geophysics Laboratory and Wentworth Institute of Technology. My greatest gratitude and appreciation go to all people involved with this project. Thanks are due to Christopher Hill who designed most preliminary circuits and Michael D. Pedersen who assisted throughout all design phases, from breadboarding to final fabrication and testing of the Multi-Address Digital Command System. The able efforts of Larry Smart and Patrick Hurley from Wentworth Institute who implemented the electrical design into a well constructed and reliable command system are greatly appreciated.

*Development of the Multi-Address Digital Command System is only one of Hans Laping's many valuable contributions to the Air Force Scientific Balloon Program. After his death his draft manuscript was completed and edited by C. L. Rice and R. E Cowie, Jr.

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1. INTRODUCTION

The Geophysics Laboratory provides balloon flight-test support for R&D payloads to the Department of Defense, its contractors and other government agencies. For every flight a highly secure (reliable) radio-command system is required to maintain control of the vehicle - to valve off lifting gas, or drop ballast, or terminate the flight. (The termination command cuts away the balloon from the recovery parachute attached to the payload). The experimenters must also be able to manipulate their instruments by remote command-control; they may need to turn devices on/off, shift measurement scales, operate pointing controls, or change optical filters, for example.

The primary intent for this undertaking was to update and increase the flexibility and security of our balloon command equipment. A great need existed to replace our old Inter-Range Instrumentation Group (IRIG) multiplexed tone command system. Most of our balloon flights are launched at or near a National Test Range, and most U.S. National Test Ranges also use IRIG tone systems in their command-destruct devices. Because we had no control over other users' tone-multiplexing schemes, our IRIG tone system was becoming more and more susceptible to outside interference. Sharing a common standard with other groups in a command system is never very good practice. Users from different organizations may have higher priority programs, and the possibility of mutual interference can create logistical problems with other missions such as drone, aircraft or missile tests. This potential conflict was a prime consideration during the search for a new command system for balloon operations.

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Our existing multiplexed audio tone system, as configured, used 9 commands with two-tone combinations, and 12 with three-tone multiplexing, so that the system was limited to 21 commands per radio link. The increasing sophistication of our balloon-borne experiments required a much larger command capability.

A third drawback in our IRIG system was that the tone decoders could be driven only by wide-band, frequency-modulated command receivers because the highest frequency in this system was close to 20 kHz. The commercially available tone decoders were also very sensitive to the drive level applied to the filters - overdriving these filters would generate undesired outputs. On long-duration, high-altitude balloon flights, the payloads can receive radio signals from locations several hundred miles away. We needed to make the command system flexible enough to utilize other frequency bands for remote control of our balloon payloads. It was, therefore necessary to decrease the required bandwidth of the modulation signals so that high frequency (HF) and narrow-band very high frequency (VHF) radio signals could be used for commanding balloon payloads at great distances from ground control. In the new command system this goal was achieved by limiting the modulation frequency to 2 kHz. The compromise in execution speed is not really a problem for slow-moving balloon payloads.

Our balloon-borne payloads routinely carry two independent command receivers, the primary and a backup. A command is issued in two stages: first, the address and the command number. The address designates an individual decoder on the payload; the command number designates one of the specific control functions associated with that address. Then, to prevent activation of an erroneous command, a reply code unique to each command is telemetered back to ground control. After the operator has verified that the command being received at the payload is the same as was actually issued from ground control, the operator issues the Execute command.

The Multi-Address Digital Command System 2A developed under this work unit solved most of the shortcomings in the IRIG tone system. It is highly secure, provides 10 addresses (0 through 9) with 95 individual commands, and can be used with all of the HF, VHF and UHF communications systems in our inventory.

2. APPROACH

To save time and effort we first searched for an off-the-shelf new command system. We also investigated using an RS-232 MODEM link. Both approaches led us back to the problem of radio interference that might falsely trigger our commands and thus decrease the security of the command links. Since the optical line of sight of a balloon floating at 100,000 feet is about 390 statute miles, interference can be received from many sources when VHF or UHF command links are operated on a long-duration, high-altitude balloon flight. The problem is even greater with HF command links because interfering signals can be received from thousands of miles away regardless of the altitude of the receiver. These facts indicated that we should develop a non-standard, digital command system with the highest degree of security and reliability.

While investigating possible choices of command encoders and decoders we came across a telephone-monitored fire alarm system manufactured by Larse Corporation of Santa Clara, California. The Larse system is used in high electrical noise industrial environments. Their encoding and decoding scheme is highly sophisticated and secure. It also has a high degree of noise immunity, ideal for our needs. We also investigated some C-MOS integrated circuits made for remote control of television and communication receivers. After extensive testing in the laboratory, we favored the Larse system without any reservations.

Before making the final selection we subjected the Larse units to a two-week continuous test under various conditions: for three days, with the output of an AM broadcast receiver fed into the decoder unit, we monitored the outputs of all 16 digital-code input lines without once detecting a change on any output. We followed the same procedure with an FM broadcast receiver for four days and again no false bit changes were detected. We then connected the decoder to an AM high frequency communications receiver with a 20-kHz intermediate frequency bandwidth to pick up as much noise and signal as possible at random selected frequencies. Again the test results were perfect. These results left no doubt that these units were suitable for command decoders in our balloon control system where strong interfering signals are frequently encountered.

Temperature tests also indicated that these encoders and decoders were suitable for our applications. Our balloon-borne instruments are normally protected by styrofoam containers that maintain good thermal insulation and at the same time cushion the landing shock of the control and telemetry modules of the payload. We seldom encounter temperatures below freezing inside our control packages. The operating range for the Larse units exceeds all temperature ranges expected for our balloon payloads.

3. DEVELOPMENT

We designed and fabricated four versions of the complete command generator: two prototypes (1A and 1B), a rack-mounted Model (2A-R), and a portable Model (2A-P). The 2A-P model was designed mainly for remote field operations where transportability and rugged construction are very important. It is similar in its function to the 2A-R rack-mounted version, but its use is not quite so flexible. A mechanically modified portable model was also fabricated and installed into our chase aircraft for backup and emergency command-control capability.

During prototype development every important circuit was breadboarded on wirewrap boards and extensively tested in the laboratory. Prototype models of the command generator and decoder were then fabricated and operated during an actual balloon flight. The test results were excellent: more than 200 commands were selected and successfully executed using HF, VHF and UHF receivers. (One design criterion was that the system should be operable with all command receiver types in our inventory in the HF to UHF range, with either amplitude or frequency modulation.)

Wirewrap construction proved unsuitable for field use and troubleshooting. During the first flight one of the command generators was mounted in the recovery-chase aircraft to test its operation for back-up command-control. The aircraft vibration caused problems with the wirewrap pins. Our interim solution was to put heat-shrinkable tubing on every second pin on the wirewrap boards. After the first flight the design concept was accepted but some redesign and a change in fabrication method were in order.

Of the 16 input data bits provided, the Larse SEN unit allots 6 for the address, 7 for the command, 2 for parity check and 1 for command activation. For our addresses (0 through 9) we chose to use just 4 bits; the extra two are grounded. With this arrangement all ten addresses in our system are programmed with a single binary-coded decimal (BCD) switch. The specifications for the SEN unit are listed in Table 1.

In our first prototype command generator we programmed all addresses and commands using BCD thumbwheel switches without BCD-to-binary conversion. This limited the number of selectable commands to 79. (In BCD, each decimal digit is separately encoded in binary bits: the code for 79 is 111 1001, which uses all 7 bits allotted for the command number.)

Verification of the selected command was accomplished by feeding the BCD command bits received at the decoder to an 8-bit straight binary digital-to-analog (D/A) converter. The output was a reply voltage equal to 0.05 V times the decimal value of the total straight binary count. The telemetered reply was awkward to interpret: after every ninth command number there was a large increase in the reply voltage. For example, command 9 provided an output of 0.45 V (9×0.05), whereas command 10 generated 0.8 V (16×0.45). This was another area requiring redesign to remove the confusion factor - an important consideration at ground control.

For the second prototype, fabrication of the airborne command decoders was changed from wirewrap to printed circuit boards. The BCD programming for the address was not changed because the address bits are not used in generating the command reply voltage. But all command generators were retrofitted with a BCD-to-binary programmable read-only memory (PROM) for command selection so that the BCD switches could be used to program the command bits in more logical fashion. With this change, each command selected provides a reply voltage equal to the command number times 50 mV. (See Table 2.) When the command is executed, 0.025 volt is added to the reply voltage to indicate that the command is ON.

The voltage level of 50 mV per selected command was chosen because the D/A converters in our ground telemetry station convert the received telemetry signal to a 10V full-scale range. For example, 50 mV (command #1) is displayed as 0.10 V. Therefore the selected command number can be read directly from a voltmeter by mentally shifting the decimal point one position to the right, a very simple procedure.

To prevent overdriving the FSK filter in the command decoders, every command receiver used with this command system was modified to include an audio amplifier compression circuit. The compression circuit uses a true rms-to-dc voltage converter to control the drive level to the decoder. This circuit increases the dynamic range of the acceptable signal level to about 70 dB without any degradation in the security of the command system.

Increasing the dynamic operating range of the decoder is especially important when HF command receivers must be utilized. By eliminating the need for precise adjustment of the modulation level by control operators with limited experience, the increased dynamic range also helps when we use command receivers from different manufacturers which do not provide the same output for a given modulation level whether the modulation type is AM or FM. (Precise modulation-level adjustment was always a source of great concern in the IRIG command system because overdriving the IRIG tone filters could simultaneously activate more than one command channel - a potentially dangerous situation.)

Table 1. SEN Unit Specifications

Manufacturer	Larse Corporation
Model	LCS-150-360
Power	12 Vdc at 25 mA (inputs open) 66 mA (inputs closed)
Bit rate	360 bits/sec
Frequency	1440 Hz to 1800 Hz
Frequency stability	0.05% (crystal controlled)
Audio output	-30 dBm to 0 dBm, adjustable (0.774 mV to 0.774 V)
Output impedance	600 Ohms
Data Inputs	16 bits 6 bits - address 8 bits - commands 2 bits - parity
Control inputs	Force ON all outputs Force OFF all outputs (used in testing only)
Input protection	+/-500 V
Logic input	1: 8 to 12 V (OFF state) 0: 0 to 1.5 V (ON state)
Outputs	15 mA sink (ON state = 0 V)
Security	double scan with parity (determined by decoder)
Communication mode	Continuous and OFF
Transmit command	SEN unit transmits as long as command is ON
Transmission time	0.212 sec. (double scan)
Operating temperature	-30 C to +75 C
Dimensions (inches)	7.5 (L), 3.2 (W), 1.07 (H)

Table 2. Command Number versus Reply Voltage

Cmd	Volt	Cmd	Volt	Cmd	Volt
None*	0.00	32	1.60	64	3.20
01	0.05	33	1.65	65	3.25
02	0.10	34	1.70	66	3.30
03	0.15	35	1.75	67	3.35
04	0.20	36	1.80	68	3.40
05	0.25	37	1.85	69	3.45
06	0.30	38	1.90	70	3.50
07	0.35	39	1.95	71	3.55
08	0.40	40	2.00	72	3.60
09	0.45	41	2.05	73	3.65
10	0.50	42	2.10	74	3.70
11	0.55	43	2.15	75	3.75
12	0.60	44	2.20	76	3.80
13	0.65	45	2.25	77	3.85
14	0.70	46	2.30	78	3.90
15	0.75	47	2.35	79	3.95
16	0.80	48	2.40	80	4.00
17	0.85	49	2.45	81	4.05
18	0.90	50	2.50	82	4.10
19	0.95	51	2.55	83	4.15
20	1.00	52	2.60	84	4.20
21	1.05	53	2.65	85	4.25
22	1.10	54	2.70	86	4.30
23	1.15	55	2.75	87	4.35
24	1.20	56	2.80	88	4.40
25	1.25	57	2.85	89	4.45
26	1.30	58	2.90	90	4.50
27	1.35	59	2.95	91	4.55
28	1.40	60	3.00	92	4.60
29	1.45	61	3.05	93	4.65
30	1.50	62	3.10	94	4.70
31	1.55	63	3.15	95	4.75

* Zero Volts is the output of the A/D converter when all commands are deactivated. The voltages above represent the A/D converter output when a command is "Selected". When a command is "Executed" a voltage of 0.025V is added to indicate the final activation of the Selected command.

This second prototype was limited to 31 command channels. It was used without any major problems on more than 15 operational balloon flights as an interim replacement for the 21-channel IRIG tone command system. After several flights we did develop a problem with the edge card connectors in the decoder units. This forced us to replace the problem connectors with a different type that was retained in the final version of the command decoders.

All shortcomings found in the first two prototype stages were corrected in the final design called the 2A Digital Command System. This is now an operational system, used in all of our high-altitude balloon-control payloads.

4. SYSTEM OPERATION

The digital command generator creates the encoded signals needed to activate commands from the control station on the ground (or in the chase aircraft) to the balloon payload. The Larse Data Communicator SEN module provides 16 data input lines (digital bits) to select and execute a command. We use 4 of the 6 assigned for address selection, 7 for command selection, 2 for parity check, and 1 for command execution. The remaining 2 of the 6 SEN-assigned address bits are grounded.

The operator enters first, the decimal address number (0 through 9), next, the command number (1 through 95), and then presses the switch marked SELECT to activate a transmit circuit in the generator that creates the programmed serial code. This serial code frequency-shifts an oscillator-amplifier circuit whose frequency-shift-keyed (FSK) audio output modulates the uplink transmitter. At the balloon, the command decoder receives the serial code and performs a serial-to-parallel conversion for the address and command number. The corresponding command reply code is telemetered back to ground control and after verification the operator presses the EXECUTE switch to activate the desired remote command. A more detailed description of the command system is given below.

5. THE LARSE SEN MODULE

The brain of the command generator is the Larse Data Communicator SEN Module. (Since both the SEN Module and the REDE decoder are described in detail in the Data Communicator Technical Manual[1], these modules are described only functionally in this report.)

The SEN module has 42 input-output pins, including the 16 data pins (see Table 3). It is enclosed in a plastic case to protect internal circuits from dust and moisture. Internally, all timing, code and synchronization signals are derived from a stable, crystal-controlled oscillator. Data entry is synchronous with an end-of-word pulse; data cannot change until the next end-of-word pulse appears.

We chose a SEN module with a bit rate of 360 bits per second that frequency-shifts the output signal between 1440 Hz and 1800 Hz. Two reasons for selecting this unit were that it operates at a non-standard bit rate, and the FSK signal is not an American Standard Telephone Modem frequency.

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1. *Data Communicator Technical Manual*, Larse Corp., Santa Clara, CA 95050.

Table 3. Input and Output Functions of LCS-152-360-1 SEN Unit

Pin No.	Function (as used in Command System 2A)
1	open (not used)
2	grounded
3	Power ground (+ 12 V return)
4	Synchronization pulse (negative pulse, testing)
5	no connection (transmission indicator)
6	Transmit command continuous (enable = 12 V in)
7	Grounded (hold memory reset)
8	not used (change alarm reset for pin 17)
9	Grounded (only used for expander unit)
10	Code output (for testing only)
11	Force OFF (ground this pin turns outputs OFF)
12	Force ON (12 V to this pin turns outputs ON)
13	Data input bit 15 (Address BCD - 8)
14	Data input bit 14 (- 4)
15	Data input bit 13 (- 2)
16	Data input bit 12 (- 1)
17	not used (change alarm output, reset from pin 8)
18	Ground (signal)
19	Ground (data inputs)
20	Data input bit 11 (Address, grounded = ON)
21	Data input bit 10 (Address, grounded = ON)
22	Data input bit 9
23	no connection
24	Data input bit 8
25	Data input bit 7
26	Data input bit 6
27	not used (single word command input)
28	not used (sync to Expander)
29	not used (code from Expander)
30	Data input bit 5
31	Data input bit 4
32	Data input bit 3
33	Data input bit 2
34	Data input bit 1 (parity input)
35	Data input bit 0 (parity input)

Table 3. Input and Output Functions of LCS-152-360-1 SEN Unit (Cont.)

Pin No.	Function (as used in Command System 2A)
36	+ 12 V Power input
37	+ 12 V (external time slot reset, not used)
38	open (not used)
39	FSK audio output adjust. A resistor tied
40	between 39 and 40, if open output is 0 dBm
41	FSK audio signal output
42	FSK audio ground

With this choice we were trying to prevent possible interference from users of standard bit rates and standard modem frequencies. (Command activation speed is not one of our greatest concerns because floating balloons move at relatively slow speeds.)

The SEN module also generates a non-standard output code that is unique to the Larse Data Communicators. These choices, we feel, increase the security of the command system. However, the real security of the command system is in the error checking and decoding scheme incorporated in the airborne command decoder. The decoder is described in Section 9 of this report.

6. PORTABLE COMMAND GENERATOR 2A-P

6.1 Control Panels

The portable command generator 2A-P (Figure 1) has a rugged steel case to protect all internal components. All front and back panel switches and connectors are recessed to keep the chance of damage during shipping to a minimum. The front-panel switches provide power turn-on, command selection, and execution, and the controls to key two independent command transmitters. The first thumbwheel switch programs the decimal address, and the second and third, the decimal command number. These settings are displayed by the digital LED readout located above the thumbwheel switches.

The audio BNC connector serves as a test point for the amplified FSK output from the SEN unit. This output can also be used to modulate an RF generator when testing the command system in conjunction with a command receiver. The FSK output-level potentiometer, located next to the BNC connector, can be adjusted with a screwdriver.

The back panel (Figure 2) shows two transmitter output connectors J1 and J2; two screwdriver adjustable potentiometers R1 and R2 for modulation level control for the transmitters; and two fuses F1 and F2 that protect the transmitters. Two banana jacks can be used to supply external DC power (28 V) to the command generator when two transmitters have to be keyed simultaneously, or the ac plug can be utilized to drive an internal power supply which is limited to 2.5A at 25 Vdc. The ac fuse F3 located above the ac plug protects the internal switching power supply. A BNC connector wired in

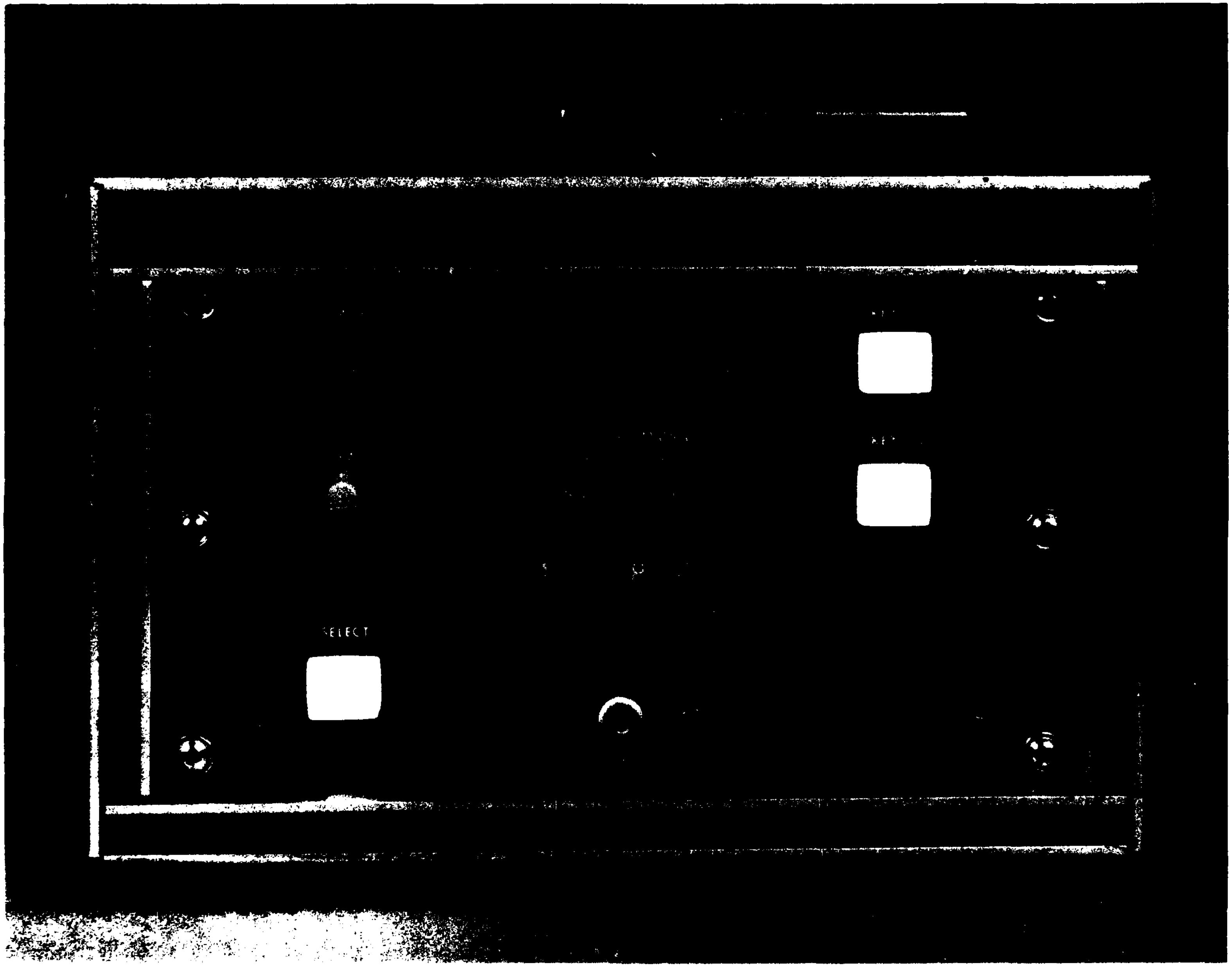

Figure 1. Digital Command Generator 2A-P (Front View)

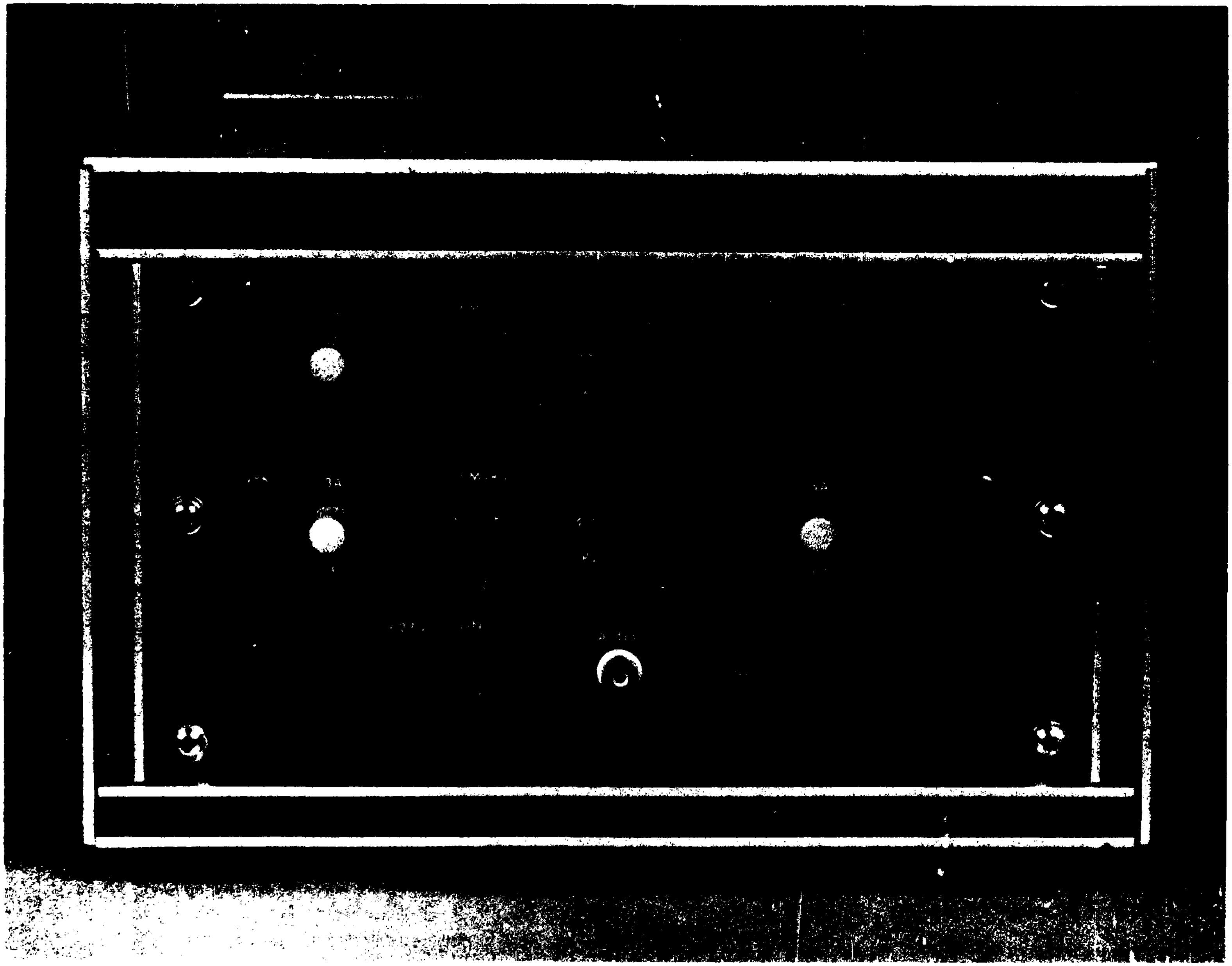

Figure 2. Digital Command Generator 2A-P (Rear View)

parallel with the front panel BNC audio FSK output can be used to drive long coaxial cables to distribute the FSK signal to remotely located transmitters. The adjustment for this output is located on the front panel next to the audio BNC connector.

6.2 Internal Layout

The internal view of the portable command generator 2A-P (Figure 3) shows the major components mounted inside the generator unit. The power supply occupies almost half the available room. The interface printed circuit board with the SEN unit plugged into the bottom of the board is mounted next to the power supply. Two regulators attached to a bracket behind the power supply provide stable voltages for the internal circuits.

6.3 Block Diagram

The block diagram (Figure 4) shows all important functional elements in the 2A-P command generator.

The portable command generator can be operated from either the internal ac power supply, which generates 25 Vdc and 5 Vdc, or from an external 26 to 32 Vdc power supply or battery. The internal 5 V output of the power supply is not used, thus only one external power source is required if the generator is battery-powered. The 25 V output from the power supply provides the voltage to 12 V and 5 V regulators, to the indicator lights inside the switches, and to the external command transmitters via the key switches. The 5 V regulator provides the proper voltage to about half the circuits in the command generator. The remaining circuits are driven from a 12 V regulator.

The internal supply is limited to a maximum of 100 W power output; therefore, if the total power requirement of the internal circuits and the external transmitters is more than 100 Watts, an external supply must be used. Care should be taken to insure that the output of the external supply is at least 1 volt higher than that of the internal supply. For safe operation of the command generator either the internal or an external supply should be used, not both, because if the external supply voltage is lower than the internal 25 V output, all circuits will still operate from the internal supply and overloading can occur.

6.4 Command Sequence

To best describe the function of the portable command generator 2A-P using the block diagram in Figure 4, let us follow the sequence of issuing a command and modulating an external command transmitter with the FSK output. For example, let us activate command channel 995, the highest command number in the digital command system as we have it configured. The generator is powered by the internal ac supply, which feeds the 12 V regulator. The 12 V regulator supplies power to the SEN unit, the audio amplifier, the parity generator, the 5 V to 12 V level shifter-inverter and the 5 V regulator. The 5 V regulator provides power for the BCD-to-binary EPROM, the LED displays, the latch circuit, the level shifters and the logic interlock circuit.

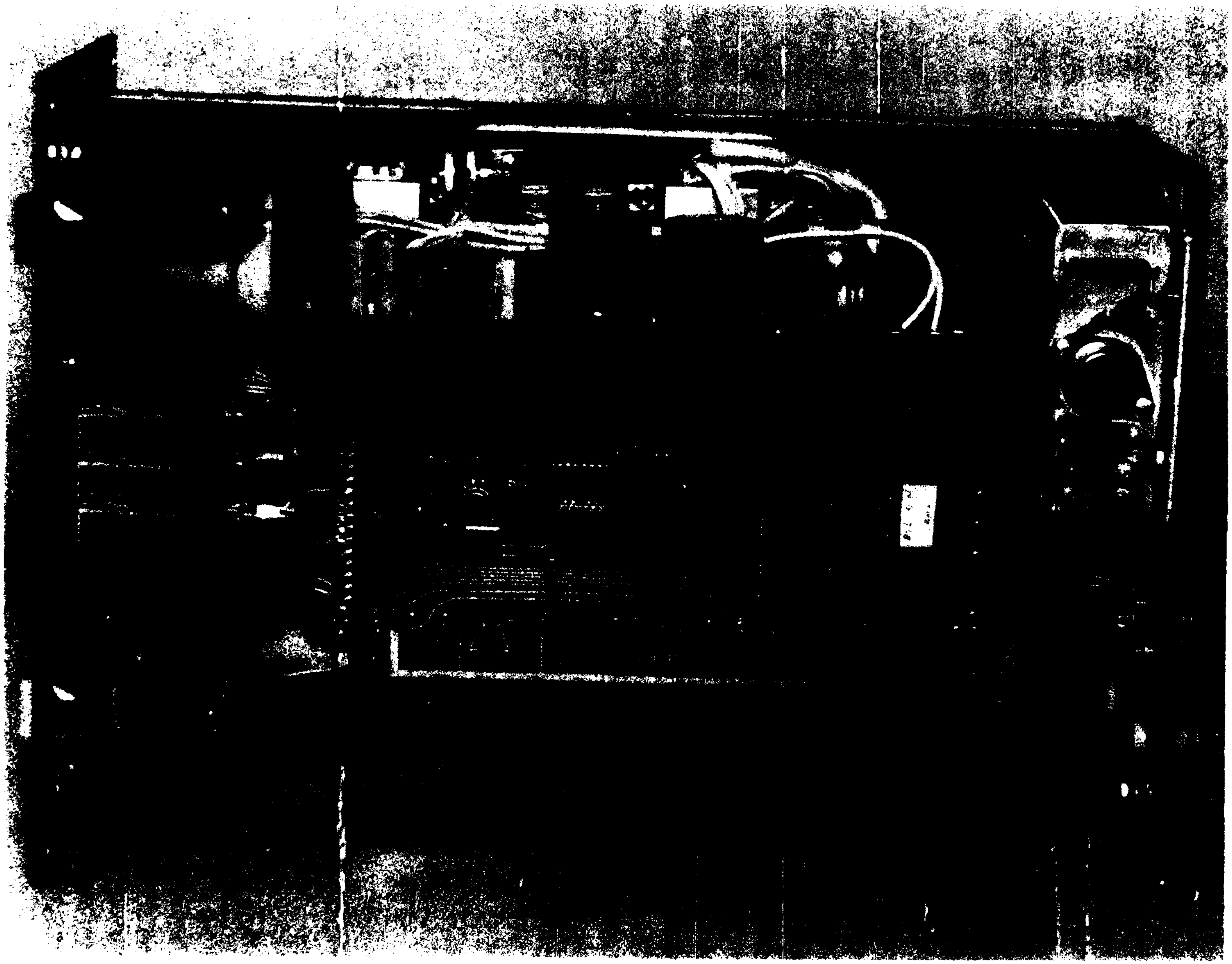

Figure 3. Digital Command Generator 2A-P (Internal View)

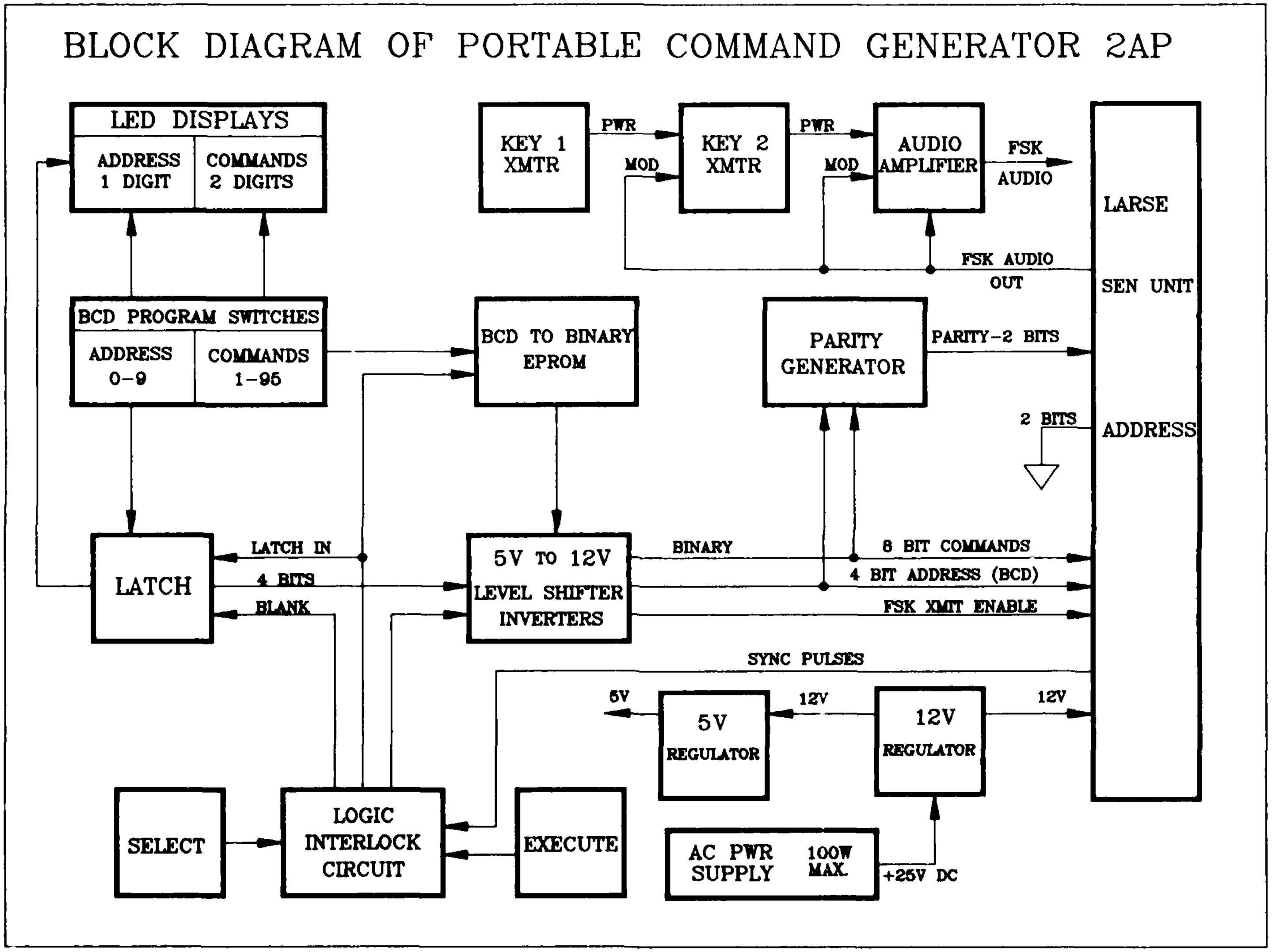

Figure 4. Block Diagram - Digital Command Generator 2A-P

We set the first thumbwheel switch to number 9, the command address. The number 9 is now displayed in the left-most LED display (See Figure 1); the remaining command displays are still blank. Next, we program the command number 9 and 5 with the second and third command thumbwheel switches, and depress the "Select" switch, which triggers the following sequence of events: The LED readout displays the number 995, and the latch is locked, which freezes the command display, the address bits, and the EPROM command output bits. Simultaneously the FSK transmit command is enabled. All input bits are 5 V level signals that are inverted and transformed to 12 V levels before they are applied to the SEN unit.

The parity generator checks all address and command bits and provides an output to the two least significant bits of the SEN unit. The parity output is low if an even number of inputs bits are on low, and the output is high if an odd number of input bits are on low. Parity bits in the command generator are precisely like any other input. However, at the airborne command decoder they play a very significant role and add to the security of the command system. The command decoder performs parity checks on all bits and disables parallel data output unless the parity received is identical to the parity transmitted by the command generator.

Once the FSK transmit command is enabled, the SEN unit generates a serial code that frequency-shifts the audio output signal between 1440 Hz and 1800 Hz. This signal provides the modulating signal for two command transmitters and also feeds the audio amplifier. The signal output levels to the transmitters and the amplifier gain are independently adjustable so that all three outputs can be at different levels.

Depressing Key switch 1 or 2 applies power to the corresponding command transmitter, which sends out the modulated signal to the balloon-borne receiver. The receiver feeds the demodulated signal to the command decoder where the serial code is transformed into a 7-bit parallel output and selects a command. Remember, command 995 has been selected, but not yet executed at the receiver.

In order to activate the selected command, the operator must energize the "Execute" switch. The "Execute" switch adds one more bit to the generator's FSK output code. This completed code finally activates the previously "Selected" command in the command decoder and performs the desired control function. The reverse sequence of switch deactivation is used to release a command.

The sequence of switch activation is important. If the "Execute" switch is activated before the "Select" switch, the logic interlock circuit prevents command selection, indicated by a blank command display. The FSK transmit enable command will also remain disabled until the correct sequence of command selection is performed. This interlock feature was included so that the command operator must verify the selected command before an attempt is made to activate the selected command channel. Once a command is "Selected" (Select switch on), command entry becomes deactivated even if the thumbwheel switches are programmed to a different number. The selected command number is always the same as the LED display indication. This feature prevents false command selection while another command is activated.

7. TEST PROCEDURE

A separate test box was designed to test the command decoders with the portable command generator so that proper operation of the whole command system can be verified before flight.

8. RACK-MOUNTED COMMAND GENERATOR 2A-R

The rack-mounted command generator 2A-R (see Figure 5) is functionally very similar to the 2A-P portable version described above, but it has some additional features. Rather than requiring the separate test box mentioned above, the rack-mounted generator incorporates circuits used to test the airborne command decoders before and during a balloon flight. Also, the thumbwheel switches used to program commands have been replaced with a numeric keyboard for faster command entry.

9. DIGITAL COMMAND DECODER 2A

Figure 6 is a block diagram for the balloon-borne command decoder system for the 2A command system. The automatic gain-control amplifier limits the drive level of the FSK audio data stream from the command receiver into the FSK filter in the REDE decoder. The station address for a Larse REDE decoder is set by the ON/OFF positions of the eight switches in the Address Selector. Table 4 shows the switch positions for each of the ten possible addresses.

Table 4. Address Selection for Command Decoder 2A

Address	Switch Settings							
	1	2	3	4	5	6	7	8
0	ON		ON		ON		ON	
1		ON	ON		ON		ON	
2	ON			ON	ON		ON	
3		ON		ON	ON		ON	
4	ON		ON			ON	ON	
5		ON	ON			ON	ON	
6	ON			ON		ON	ON	
7		ON		ON		ON		
8	ON		ON		ON			ON
9		ON	ON		ON			ON

* A blank square indicates that the switch is OFF! All ten addresses are valid and can be used as unique address codes. If all switches are off, then any address chosen by the command generator will activate the selected command channel.

Figure 5. Rack-Mounted Digital Command Generator

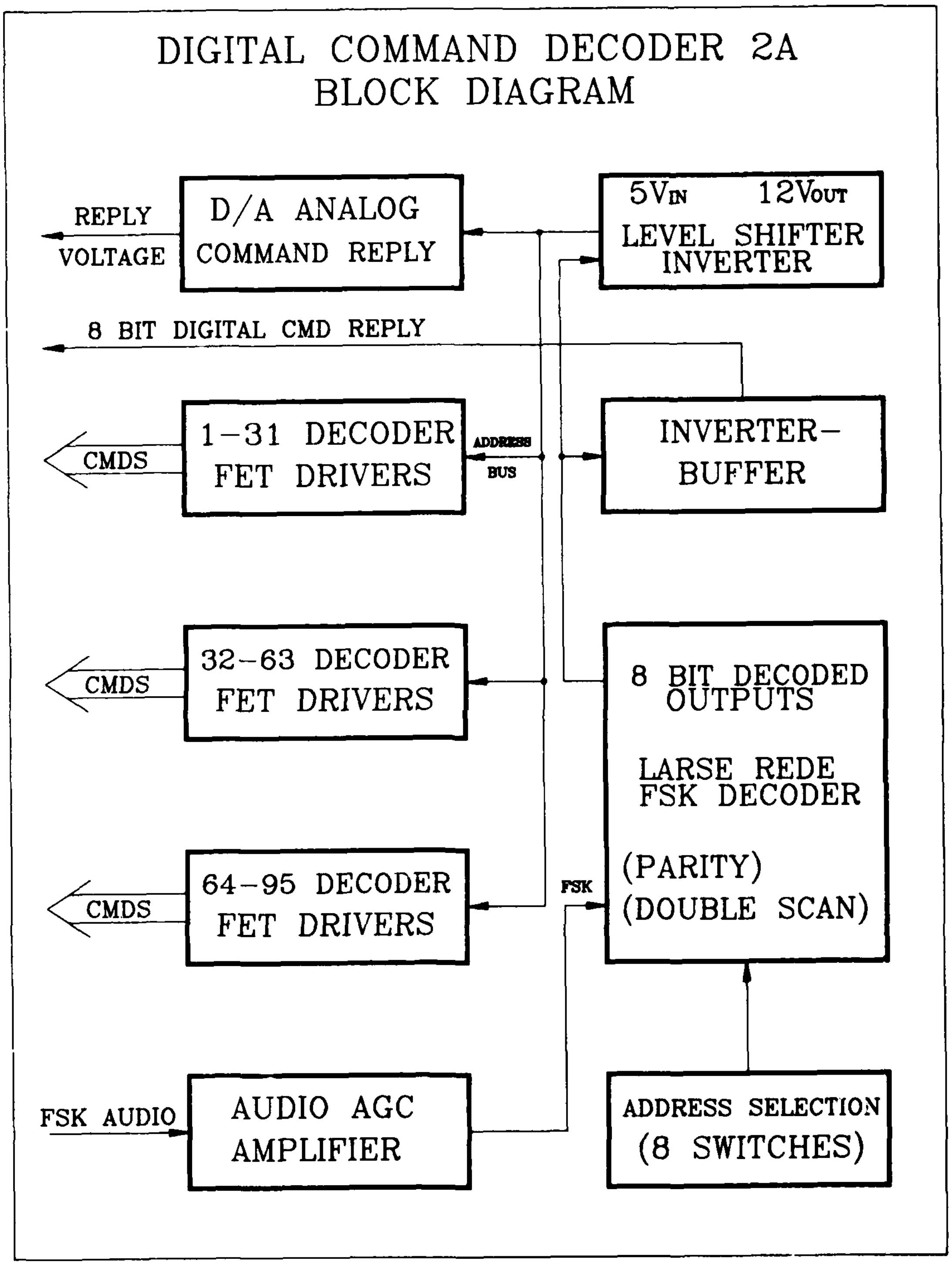

Figure 6. Block Diagram - Digital Command Decoder 2A

The REDE unit performs a double-scan parity check on the transmitted code and verifies the encoded address. When the status of all 16 SEN data points has been validated, they are released as a group at the output terminals of the REDE unit. The decoded 8-bit command is applied to a 5 V inverter-buffer and also to a 5 to 12 V level-shifter/inverter. The level-shifter/inverter provides the command code for the individual FET relay drivers that actually execute the commands. The digital output from the level shifter-inverter is also input to a digital-to-analog converter to provide the corresponding command reply signal for modulating an analog downlink back to ground control. The inverter-buffer provides the 8-bit digital command reply signal when transmission is to be via a digital downlink system to ground control.

10. CONCLUSION

The Digital Command System, either Model 2A-P (portable) or Model 2A-R (rack-mounted) has been the standard command instrumentation for the Geophysics Laboratory's scientific balloon flights since 1986. On every flight it has provided error-free operation.

Reference

1. *Data Communicator Technical Manual*, Larse Corp., Santa Clara, CA 95050.